Detector Geometry used for Geant 4 Balloon Test Simulator

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1 Overview

Geant4 is a toolkit for the detector simulation to reproduce the interaction between high energy particles and matters in detectors, and is utilized as Monte-Calro simulator for a Balloon Flight for GLAST. In order to build a reliable simulator, geometry of the real instrument should be appropriately included in source codes. In this document, we summarize detector geometry of the Balloon Flight Engineering Model (BFEM) in a Geant4 simulator. A comparison with TBsim geometry and the real instruments is important to validate the simulator.

2 Detector Geometry

Instruments of the Balloon Flight is based on the Beam Test Engineering Model (BTEM). It consists of one tower (Tracker, Calorimeter, and Anti-Coincidence Detector enclosed in Carbon Wall) and some newly added components (External Target, Pressure Vessel and VME Crate). To construct a geometry of components that was used for BTEM in the simulator, we referred to specification documents (“GLAST Testbeam Users guide” of Ver 1.5 [1], “Geometry for the TRACKER to update .XML” [2], and “.XML file used for GLASTSIM input” [3].) For densities and mass numbers of elements and materials, we used the value in ”The European Physical Journal” (2000).

A schematic view of the BFEM geometry is shown in Figure 1. Below we describe details of the geometry of each part.

[1] http://www.slac.stanford.edu/~hansl/glast/bt99/bt99.bk.pdf
[2] http://www-glast.slac.stanford.edu/testbeam/geometrytkr.ppt
[3] http://www-glast.slac.stanford.edu/testbeam/tbinstrument.xml

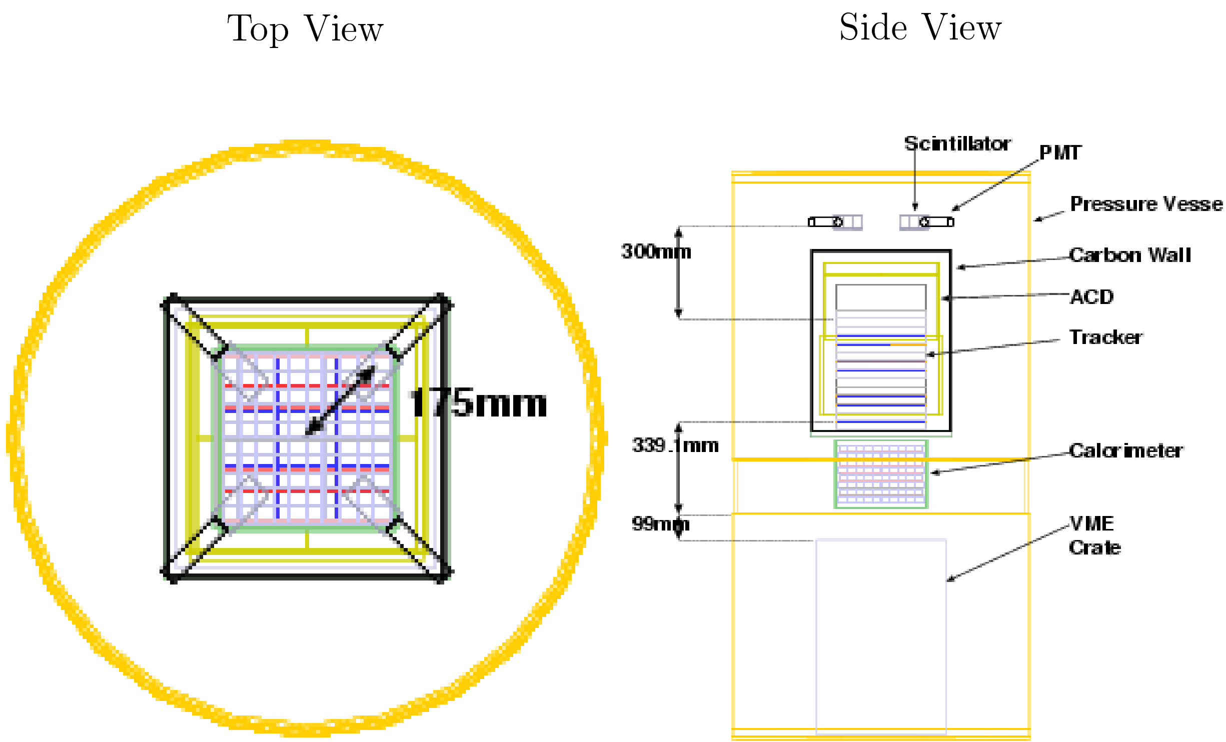

Figure 1: A geometry in the current Geant4 Balloon Test simulator.

2.1 Tracker (TKR)

A Tracker (TKR) of BTEM consists of 16 x,y planes of Silicon Strip Detectors (SSDs), lead converter foils, and the associated readout electronics, all supported by a carbon-composite structure. Here, "x" and "y" mean plane that can measure x and y direction, respectively. The support structure for the detectors and converter foils is composed of a stack of 17 composite panels, call "trays,". As for BFEM, three trays are removed to reduce the mass of the detector.

The structure of one tray (a standard tray; see below) is shown in Figure 2. In one tray, two layers of SSD are placed on the top and bottom and lead converter layer lies between these two SSD layers. Each tray is arranged alternatively in two perpendicular directions so that the bottom SSD layer of one tray and the top one of the next tray work as x and y planes. There are 8 x,y trays from the top of the TKR with 3.5% radiation length converters ("standard trays" or "front section"), followed by 3 trays with 25% radiation length converters ("super GLAST" or "back section") and three trays with no converter foils ("no lead tray"), as shown in Figure 3. Composition of tray is summarized in Table 1.

For the beam test and the balloon flight, silicon wafers of two different sizes were used ("4-inch" and "6-inch" wafer), but strip width, strip pitch and the number of strips are the same for all detectors. Not all SSD layers are fully equipped. Layers in trays from 9 to 14 are not fully equipped with wafers, and we call these layers "an incomplete layer". Configuration of each tray is summarized in Table 2.

When constructing the detector geometry in the simulator, we arranged all the materials according to the configuration described above. Table 3 shows the sizes of each material we included in the simulator. We register silicon detectors as "sensitive detector" where Geant4 records particle tracks. Actual SSD has insensitive regions in the periphery, but we made the whole region as sensitive in the simulator, since the insensitive region is less than only a few percent. Lead converters are placed so that x and y coordinate of the center are the same as those of SSDs. Although core is composed of the honeycomb structure, we constructed it as a box of aluminum with a density 0.017 g/cm^3, which is 0.6 % of normal aluminum.

Thicknesses of each tray are also shown in Table 1. We placed trays so that top SSDs are separated by 32.0 mm with each other. Z coordinate values of each SSD are shown in Table 2.

There are some other matters around TKR. Aluminum side walls surround TKR, an aluminum stand is put under TKR, and light-shield boxes cover the whole TKR and ACDs. These materials are also included in the simulator. Elemental composition, size, and position of Aluminum walls and stand are shown in Table 4. Carbon wall is described in § 2.2.

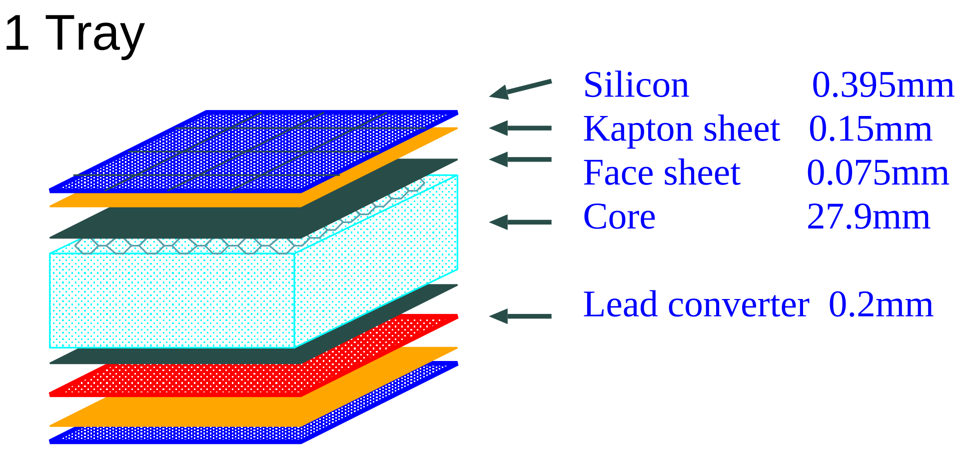

Figure 2: Schematic view of a standard tray

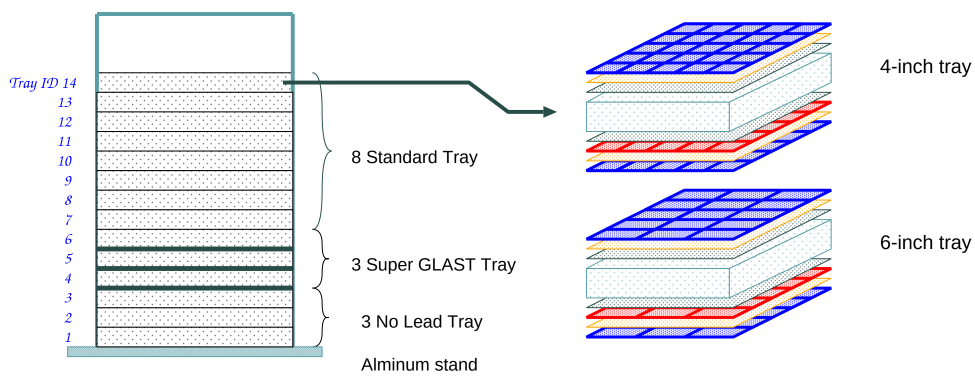

Figure 3: Schematic view of a tower

Table 1: Materials in each tray. Topmost tray is a Standard Tray without upper Kapton and top SSD, and the Bottommost tray is a no lead tray without lower kapton and bottom SSD. Thickness of trays is shown in bracket.

Bottommost Tray	NoLead Tray	SuperGLAST Tray	Standard Tray	Topmost Tray
top SSD	top SSD	top SSD	top SSD	Face sheet
Kapton	Kapton	Kapton	Kapton	Core
Face sheet	Face sheet	Face sheet	Face sheet	Face sheet
Core	Core	Core	Core	Lead
Face sheet	Face sheet	Face sheet	Face sheet	Kapton
Bottom	Kapton	SuperGlast Lead	Lead	bottom SSD
	bottom SSD	Kapton	Kapton	
		bottom SSD	bottom SSD	
(34.9975 mm)	(29.14 mm)	(29.14 mm)	(29.34 mm)	(28.795 mm)

Table 2: Tray configuration. Ladders are loaded with five small SSDs (4 inch) or three large SSDc (6 inch). The number of ladders of each tray is listed for each layer. ID numbers of SSD are also listed, with the coordinate that can be measured in brackets.

Tray	Top ladders				Bottom ladders				Lead
	No 4 in	No 6 in	Si ID	z (mm)	No 4 in	No 6 in	Si ID	z (mm)	(%Xrad)
14					3		25(x)	386.995	3.5
13	2	1	24(y)	383.94	3		23(y)	354.995	3.5
12	3		22(x)	351.94	3		21(x)	322.995	3.5
11	3		20(y)	319.94	3		19(y)	290.995	3.5
10	3		18(x)	287.94	4		17(x)	258.995	3.5
9		4	16(y)	255.94	5		15(y)	226.995	3.5
8		5	14(x)	223.94		5	13(x)	194.995	3.5
7		5	12(y)	191.94		5	11(y)	162.995	3.5
6		5	10(x)	159.94		5	9(x)	131.195	25
5		5	8(y)	127.94		5	7(y)	99.195	25
4		5	6(x)	95.94		5	5(x)	67.195	25
3		5	4(y)	63.94		5	3(y)	35.195	0
2		5	2(x)	31.94		5	1(x)	3.195	0
1		5	0(y)	0					0

Table 3: Material table of TKR

Material	elemental composition	density [g cm^{-3}]	size
4-inch Silicon	Si	2.330	$64.0 \times 64.0 \times 0.395$ mm^3
6-inch Silicon	Si	2.330	$64.0 \times 106.8 \times 0.395$ mm^3
4-inch Lead	Pb	11.35	$62.4 \times 62.4 \times 0.20$ mm^3
6-inch Lead	Pb	11.35	$62.4 \times 105.2 \times 0.20$ mm^3
Lead for super GLAST	Pb	11.35	$62.4 \times 105.2 \times 1.6$ mm^3
Core	Al	0.017	$330.2 \times 330.2 \times 27.9$ mm^3
Core for super GLAST	Al	0.017	$330.2 \times 330.2 \times 26.3$ mm^3
Kapton sheet	$C_{10}H_2O_4Cu$	1.420	$330.2 \times 330.2 \times 0.15\ mm^3$
Facesheet	C	1.20	$330.2 \times 330.2 \times 0.075$ mm^3
Bottom	Al	2.70	$330.2 \times 330.2 \times 5.305$ mm^3

Table 4: Material table of Aluminum walls and stand

Material	elemental composition	density [g cm^{-3}]	size	z coordinate of the center[mm]
side wall	Al	2.70	$330.2 \times 545.9 \times 1.5$ mm^3	238.8525
stand	Al	0.017	$528.3 \times 528.3 \times 22.6$ mm^3	-45.0025

2.2 Carbon Wall

The carbon wall is a light shield and consists of five 5mm thick carbon panels, whose density is 2.265 g cm^{-3}. One panel is placed on top of the tower and the others at each side. The positions and ID numbers of panels are listed in Table 5 .

Table 5: The information about the carbon wall, material, dimensions, and positions. The thickness of all Carbon Wall are 5mm.

Dimension(mm^2)	position of CarbonWall center			ID number of Wall
	x(mm)	y(mm)	z(mm)	
$\Delta z \times \Delta y$ 671×510	257.5	0	301.6	0
$\Delta z \times \Delta x$ 671×510	0	257.5	301.6	1
$\Delta z \times \Delta y$ 671×510	-257.5	0	301.6	2
$\Delta z \times \Delta x$ 671×510	0	-257.5	301.6	3
$\Delta x \times \Delta y$ 510×510	0	0	634.6	4

2.3 Calorimeter (CAL)

The calorimeter (CAL) consists of CsI crystals, Polystyrene films, rubber sheets, and support frames. Materials and sizes of these components are listed in Table 6.

One layer of the calorimeter consists of ten CsI crystals arranged in side by side, and eight layers make up the whole CAL. Each layer is arranged alternately in two perpendicular directions in order to get the x and y position information. Log IDs are aligned along x and y direction. They are numbered from 0 to 79 with decreasing z-value as shown in Figure 4. The layer closest to the tracker is a top layer which consists of the crystals from 0 to 9. The distance from the tracker base to CsI top panel is 9.6 mm.

Each CsI crystal is wrapped in Polystyrene films as reflector, and a rubber sheet is placed between CsI layers for absorbing the shock. The material of Polystyrene is C_8H_8, and that of rubber is C_4H_6. In order to record the deposited energy, we register all CsI crystals as the sensitive detector.

Whole CsI crystals are enclosed by frames made of aluminum as a support structure. To represent these frames in the simulator, we placed two aluminum boards on top and bottom of CAL, and four boards on each side. The density of these boards are the same as that of core in TKR, i.e., 0.6% of usual aluminum.

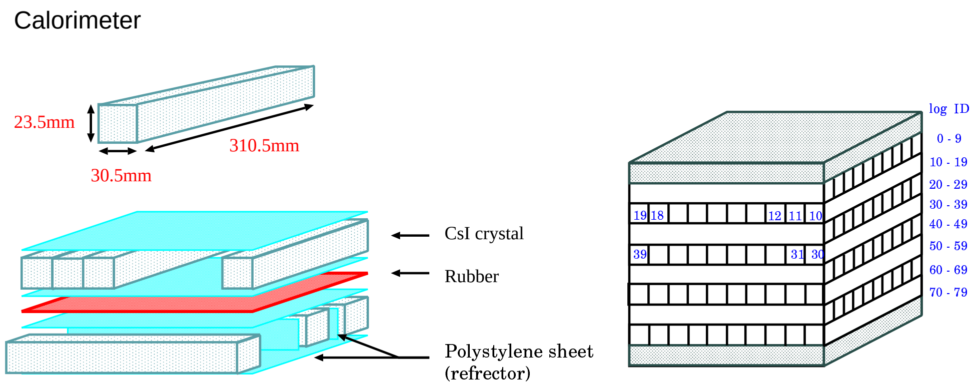

Figure 4: Schematic view of CAL

Table 6: Materials used in CAL.

Material Material	elemental composition	density [g cm^{-3}]	size (z coordinate value of the center)
CsI crystal	CsI	4.53	$30.5 \times 310.5 \times 23.5$ mm^3
Polystyrene	C_8H_8	1.032	$30.92 \times 310.5 \times 23.92$ mm^3 thickness 0.42 mm
rubber	C_4H_6	1.0	$310.5 \times 310.5 \times 2.62$ mm
CAL support frame (top/bottom)	Al	0.017	$330.2 \times 330.2 \times 20.00$ mm (-76.10/-309.06 mm)
CAL support frame (side)			$8 \times 330.2 \times 146.48$ mm (-192.58 mm)

2.4 Anti Coincidence Detector (ACD)

The anticoincidence detector identify the background events caused by charged particles and consists of twelve 1 cm thick scintillator tiles. Among them, four tiles are placed on top of the tower and eight ones at each side. Elemental composition of the scintillator is C_8H_8 of 1.032 g cm^{-3}. The positions and ID numbers of tiles are listed in Table 7. Although the top tiles are bent in the (x,y) plane of the real anticoincidence detector, the flat tiles are implemented in the simulator.

Table 7: Dimensions and positions of ACD scintillator tiles.

Dimension(mm^2)	position of scintillator center			ID Number of tile
	x(mm)	y(mm)	z(mm)	
$\Delta z \times \Delta y$ 297 $\times$ 432	221	0	172.9	4
284 $\times$ 432	211	0	448.4	10
$\Delta z \times \Delta x$ 297 $\times$ 432	0	221	172.9	3
284 $\times$ 432	0	211	448.4	9
$\Delta z \times \Delta y$ 297 $\times$ 432	-221	0	172.9	1
284 $\times$ 432	-211	0	448.4	7
$\Delta z \times \Delta x$ 297 $\times$ 432	0	-221	172.9	6
284 $\times$ 432	0	-211	448.4	12
$\Delta x \times \Delta y$ 204 $\times$ 204	103	103	545	16
	-103	103	545	19
	-103	-103	545	13
	103	-103	545	22

2.5 External Gamma-ray Target (XGT)

For a Balloon Flight, some new components are newly included. One of them is External Targets (or Active Targets), consisting of 4 sets of a scintillator and a photomultiplier tube (PMT) assembly. When cosmic-ray proton hits the scintillator, induces inelastic scattering, and π^0 mesons are generated, they are immediately decayed into gamma-rays. The scintillators of external targets are read-out by PMT, so we can obtain "tagged gamma-ray events" generated at target. The scintillator is a $50 \times 50 \times 100$ mm^3 plastic scintillator wrapped in Gore-Tex of 0.25 mm thickness (as reflector) and aluminized mylar (as light shield). Since the mass of these materials are small, we implemented only plastic scintillators in Geant4 simulator. The bottom of the scintillator is placed 250 mm (***currently 300 mm in program***) above the top of the tracker and the center of the scintillator is separated by 175 mm from the coordinate axis, as shown in Figure 1. The position of each scintillators are summarized in Table 8.

The PMT assemblies are HPK H3171-04, consisting of phototube (R1398), magnetic and light shield, and bleeder string. In Geant4 simulator, we neglected the phototube and bleeder string, since the mass of these components is small compared with that of the magnetic and light shield. We modeled the shield as Nickel tube of 0.5 mm thickness, 33 mm diameter, and 140 mm height. The mass of this Nickel tube is about 250 g, almost the same with that of PMT assembly. Support structures mostly made of aluminum are currently omitted.

Materials used for XGT are given in Table 9.

Table 8: Position of the XGT scintillator center

x[mm]	y[mm]	z[mm]	ID number in the simulator
123.74	123.74	741.19	0
-123.74	123.74	741.19	1
-123.74	-123.74	741.19	2
123.74	-123.74	741.19	3

Table 9: Materials used for XGT

Material	elemental composition	density [g cm^{-3}]	size
Scintillator	C_8H_8	1.032	$50 \times 50 \times 100$ mm^3
magnetic shield	Ni	8.85	16.25 mm (innerRadius) 16.5 mm (outerRadius) 140 mm (height)

2.6 Pressure Vessel and VME Crate

In order to minimize the potential problems in the vacuum for the detector and electronics, the tower and its electronics are housed in a vessel with a pressure of about 1.0 atmosphere. Based on a drawing distributed at VRVS balloon meeting (http://www.slac.stanford.edu/~godfrey/Balloon_pv_10-25-00.pdf), we divided the pressure vessel into three part (upper vessel, middle vessel, and lower vessel) and modeled each of them as Aluminum tubes. Parameters of these tubes are summarized in Table 10. We also placed a cover above the upper vessel and below the lower vessel, as shown in Figure 1.

We also expressed a VME Crate in Geant4 simulator. Instead of modeling a detailed structure of electronics, we simply construct a box of Aluminum whose density is 20% of ordinary material, as shown in Table 10. Position of Pressure Vessel and VME Crate are summarized in Figure 1.

Table 10: Material and size of Pressure Vessel and VME Crate

Material	elemental composition	density [g cm^{-3}]	size
upper Vessel	Al	2.70	544.5 mm (innerRadius) 10.0 mm (thickness) 1028.00 mm (height)
middle Vessel	Al	2.70	534.5 mm (innerRadius) 10.0 mm (thickness) 200.00 mm (height)
lower Vessel	Al	2.70	544.5 mm (innerRadius) 10.0 mm (thickness) 800.00 mm (height)
cover	Al	2.70	544.5 mm (innerRadius) 10.0 mm (thickness) 30.00 mm (height)
VME Crate	Al	0.54	$483 \times 483 \times 722$ mm^3